CERNA WORKING PAPER SERIES

Silicon Valley Stories

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Working Paper 2009-1

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January 2009

This paper has been presented at the EURAM annual conference, Liverpool, May 2009
An improved version in French (June 2009) is under reviewing by "Entreprises et Histoire"

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Abstract

Many countries try to promote the emergence of technological clusters and ecosystems for growth, counting on the synergies between companies of varying sizes and academic research. Most look to Silicon Valley as the mythical role model. It is therefore worth trying to understand what caused this region's exceptional development. Although abundant literature exists on the subject, it suggests a wide range of explanations. We propose to examine these accounts while trying to avoid boiling down a century of co-evolution in technologies, institutions, professional communities and markets into a few simplistic recipes that will result in inefficient state policies.

Keywords: Silicon Valley, co-evolution, industrial districts, cluster policy, regional economics

Introduction

Silicon Valley is the ultimate cluster, and its story is an unavoidable reference for anyone who wishes to imitate it or adapt it to a different local context. But what is its story in fact? Numerous accounts have been made of this Eldorado's epiphany, all of which contain at least a grain of truth. Just like in the parable of the elephant discovered by four blind men, it might prove useful to consider the different partial and complementary approaches to the phenomenon.

Most accounts make use of an explanatory mechanism, making them particularly convincing to defenders of matching theories. Here we present a succession of explanations, favoring respectively:

- the influence of the providential man whose genius changes the course of history;
- the potential of one specific technology: integrated circuits;
- path dependency, which shows that local industrial history in wireless telegraphy led to the simultaneous appearance of skills that were to prove vital to future developments;
- the role of state policy, particularly the defense ministry's supply strategy;
- the "spill-over" effect, which results when research by large companies produces excess technology that they do not develop efficiently;
- a systematic, institutional vision showing how an ecosystem of complementary institutions has grown (universities open to their environment, "integrating" legal counsels, "hands on" venture capitalists, company advisors and various consultants);

- the development of communities of practice that allow knowledge to be capitalized beyond the boundaries of individual companies;
- tolerance of biodiversity, which guarantees the presence of a highly varied pool of talents, some of which will prove useful for exploiting unexpected opportunities.

This list of competing explanations is to an extent linked to the four levels of inertia – or coherence – described by Claude Riveline (matter: electronics; man: Frederick Terman and his followers; institutions: the ministry of defense and an ecosystem of organizations that provide services to fast-growing companies, work organization; and the sacred: enthusiasm for innovation, a spirit of enterprise and tolerance) [Riveline 2006]. We also find in them Dorothy Leonard's four skills or key rigidities, which are almost the same (the technical system, employee knowledge and know-how, the management system, and standards and values) [Leonard-Barton, 1992]. If we take Claude Riveline's proposition, which maintains that we can only substantially change an organization's course by making sure the four levels remain coherent, and that if one action privileges a single level, then it will clash with the inertia of the three others — then we can deduce that these partial stories can result in inefficient policies for encouraging the emergence of clusters similar to Silicon Valley.

In this article, we will therefore recount the various descriptions of Silicon Valley's history, a combination of which tends to point to a fairly complex *co-evolution* of institutions, technologies and markets. We are currently working on its implications to understand the various, more or less successful, attempts to reproduce at least some of the characteristics of this ecosystem. We assume that most readers are familiar with the characteristics of Silicon Valley, which have been abundantly described in a large number of works [Saxenian 1991; Rogers and Larsen,1984 ; Lee 2000] and will not develop them in this paper.

Consistent, but very different, accounts

Frederick Emmons Terman, visionary (a heroic account)

After undergraduate studies in chemistry at Stanford, where his father was a professor, Frederick Terman obtained a PhD in electronics from MIT in 1924 under Vannevar Bush[1]. As a professor at Stanford in 1925, which was then considered an average institution[2], Terman transformed part of the university's reserve funds into an industrial park and encouraged some of his students, such as the Varian brothers, Bill Hewlett and David Packard to set up their companies there. At that time, most qualified employment in electronics was to be found in the East of the country, but Terman used his personal network to help his students find funding (sometimes in the form of a research grant in his department, as for David Packard), their first contracts or partnerships with established enterprises. Even so, it was difficult for companies to survive far from the research and decision centers of the East Coast[3].

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[1] Vannevar Bush, "the good Bush", scientific advisor to President Roosevelt, organized the American research system and its overlapping with military needs. As President of the national committee for aeronautics, in 1940 he founded the national committee for defense research, which became the office for scientific research and development (in charge of the Manhattan project for developing the atomic bomb). After the war, he was an ardent defender of massive investment in fundamental research. The famous report he made to the president in July 1945, "Science, the endless frontier", led to the creation of the National Science Foundation (NSF) in 1950, after a legal battle that lasted years between supporters of applied research in which results would belong to the state, and supporters of fundamental research to be governed by scientists and authorizing private patents. He described concepts that are considered as precursors of the World Wide Web.

[2] The university was created at the end of the 19th century by senator Stanford in memory of his deceased son, Leland Junior. Leland Stanford Senior was a local entrepreneur who had made a significant fortune in the gold rush by having the railway line built from the coast to the Eldorado gold field using Russian and Chinese immigrants in fairly miserable conditions, even for the time. Before WWII, the young university's main claim to fame was that President Herbert Hoover had done his undergraduate studies there in the first academic intake when the university opened in 1891. However, the young impoverished orphan was not in a position to apply to a more prestigious seat of learning. He financed his mine engineering studies there with numerous odd jobs. Hoover was triumphantly elected in 1928, but was unable to overcome the 1929 financial crisis and the Great Depression, despite his pragmatism and sensitivity to social issues (in 1932 he raised upper tax limits from 25% to 65%).

[3] Although the Varian brothers managed to secure a contract to develop the klystron invention in 1937, the company to which the operating license had been granted, Sperry Gyroscope, closed its West Coast laboratory in 1940 and made the brothers come to the Long Island laboratory, along with their teachers William Hansen and Edward Ginzton (possibly in order to carry out their research on a secure site working for the Defense).

After spending the war running the Harvard laboratory of radar countermeasures, Terman returned to Stanford as head of the engineering school and then provost of the university[4]. He used his personal network to promote Stanford's relations with companies and agencies financing research into defense. He encouraged the creation of a consulting activity (which became autonomous at the end of the 60s), called the Stanford Research Institute. He created "industrial affiliate clubs" in certain departments, with members paying a fee to gain privileged access to current work. He opened up training leading to a diploma for company workers (Honors Cooperative Program). Much later on, when technically possible, teaching took place by video transmission with sound relayed into the amphitheatre, so that staff from member companies could take part in lessons from a specially equipped classroom in their office building.

All of these initiatives drew research centers from technological companies to the region and created a favorable environment for the development of new enterprises.

The Silicon Valley legend draws in particular on the close link between the emergence of start-ups and Stanford (the garage in which David Packard created his company is now an official historical landmark of the State of California). However, Stephen B. Adams [Adams, 2005] shows that large companies made up the bulk of Stanford's industrial relations, and others underline the role of national defense, either directly (i.e. in subsidizing research work at Stanford or SRI), or indirectly (i.e. orders placed with local electronic enterprises).

Even if they employed relatively few people, the significant network of start-ups did much for the Valley's entrepreneurial culture. "Networking", facilitated by multiple relations with Stanford, made communication between companies easier. Many young entrepreneurs benefited from advice from managers of established companies. An example is Apple, whose

[4] The provost is the university's administrator and works under the president.

two young creators (Steve Jobs and Steve Wozniak) received support from the "third man", Mike Markulla, an experienced manager from HP whose backing hunches attracted investors.

Horrible William Shockley's[5] lovely children[6] (the miraculous technology)

Frustrated that his talents were not fully valued at Bell Labs, William Shockley, who co-invented the transistor with Bardeen and Brattain[7], went on a sabbatical at CalTech in 1953. Here, his colleague Beckman, founder of Beckman Instruments, financed his company "Shockley Semiconductors Laboratories", which Shockley set up at Mountain View. Since none of his former colleagues from Bell Labs would accept to come and work with him, he hired some brilliant engineers who did, however, have trouble putting up with his paranoid management style. In 1957, eight of these researchers, "the traitorous eight", left to set up a new company together, financed by Fairchild Camera & Instruments, of which it became a subsidiary[8]. Two of them, Gordon Moore and Robert Noyce, left Fairchild to set up Intel soon after, when the mother company became caught up in in-house problems and gave its subsidiary too little attention, letting good opportunities go by[9].

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[5] This paragraph draws in particular on the article by Gordon Moore and Kevin Davis, "Learning the Silicon Valley way", in [Bresnahan & Gambardella 2004]

[6] Shockley was a staunch eugenicist who was alarmed by the fact that less-qualified sectors of the population had higher reproduction rates; he donated his sperm to the "Repository for germinal choice" in the aim of upgrading humanity's gene pool.

[7] Bardeen and Brattain made original patents for the transistor in 1947, but they used Shockley's theoretical works on the field effect. Shockley perfected the invention and proposed the junction transistor in 1951. The three of them shared the Nobel Prize in 1956.

[8] The traitorous eight first went to see the shareholder, Arnold Beckman, to ask if he would hire a director and make Shockley scientific director. When he refused, they looked for a director themselves and hired Ed Baldwin, Head of Engineering at Hugues Semiconductors. Ed finally left to set up a competing company (Rheem Semiconductors, sentenced for misappropriation of industrial secrets), but in the meantime, the scientists who had started up Fairchild Semiconductor had learned how to run a company for developing scientific inventions.

[9] Moreover, as we will see later, Fairchild had exercised his right to buy back the eight traitors' shares, which made them rich, but meant they no longer had an interest in the company's future. This point is not mentioned in Gordon Moore's account.

According to Gordon Moore, the concentration of several very high-level scientists and technologists and the successive spin-offs played a much more determining role in the construction of Silicon Valley than Stanford and the abundant military credits. A lot of other universities throughout the country followed the MIT model, which consisted in promoting relations with companies and encouraging business start-ups. Moore maintains that Stanford was particularly good at reacting rapidly to demands and adapting itself to the needs and skills of local businesses (the department of materials and procedures for semi-conductors was only developed following Fairchild's significant work). Fairchild also grew by targeting numerous civil applications, which called for high production levels, whereas space programs were more cautious and relied on obsolete technologies (with the exception of the Minuteman defense program, which effectively encouraged the development of the planar manufacturing technology); the military market would have been a lucrative, but secondary one. Robert Noyce's daring wager was to propose integrated circuits at cheaper prices than discrete components to assemble separately, in an attempt to convince reticent purchasers. This approach meant that Fairchild sold at a loss for a year during a period when manufacturing yields were still low, but what it did do was open up the mass market. Venture capital, which went on to play an essential role, only appeared after the first spin-offs. Arthur Rock found funding for Shockley's 'traitorous eight', when, after numerous fruitless contracts, he convinced Sherman Fairchild to create a semi-conductor subsidiary. But at that time, he was a mere business banker He became only years later one of the first and soon of the greatest valley's venture capitalists.

What was hard at the time was finding a capable leader like William Hewlett to efficiently run a company set up to exploit scientific developments. Almost all the engineers in the valley's semi-conductor industry went throuh Fairchild (95% according to a 1969 survey), but most of them came from other regions, notably the “eight traitors” and Ed Baldwyn, the first director that they hired.

According to Moore, the key to initial success was the immense potential of the rising semi-conductor technology. Stanford’s reactivity served to amplify a success that it had not started itself — that of “commercial science”, which held little interest for electronics and chemistry departments and was at the time developed by engineers “who weren’t looking to create any more knowledge than they needed”[10].

Moore maintains that start-ups create few new ideas, but are good at getting efficient hold of under-exploited ideas from big companies or state laboratories. A public policy that is too centered on providing aid to start-ups would therefore be dangerously incomplete.

There was life before Terman (the long story of electronics)

Moore puts Terman’s role and that of the university into perspective by showing that they created favorable conditions that would have simply remained latent potential but for the miraculous opportunity of the solid transistor, followed by integrated circuits, which made it possible to manufacture multiple transistors on the same chip. However, some historians remind us that Silicon Valley was far from a desert before Terman and the development of Stanford Industrial Park.

Timothy J. Sturgeon [Sturgeon 2000] thus shows us that before solid transistor applications arrived, the region of Palo Alto already had the tube transistor to thank, and even the electric arc generator, for making it a centre of competence in industry and wireless telegraphy, then radio broadcasting.

[10] Intel in fact refused to have a central laboratory, based on the reasoning that things had become much harder at Fairchild when their laboratory staff levels reached 600 and had moved away from divisions.

The invention of radiotelegraphy by Guglielmo Marconi in 1895 was initially used for civil and military navigation purposes. The various equipment suppliers were integrated firms from the east coast, all of which had mediocre overall performance levels, but jealously kept to themselves the critical components that they had developed. Cyril Elwell, a newly qualified Stanford graduate, bought a license for an electric arc transmitter from a Dane called Vladimir Poulsen, who had exhibited his invention at the Paris Exhibition of 1900. His company, Federal Telegraph (FTC) was set up in 1909 with funding from the president of Stanford, David Starr Jordan, and prospered quickly when it perfected radiotelegraphs that supplied the national navy (e.g. the liberty ships used in WWI were equipped by FTC). In 1910, Lee de Forest came to install radiotelegraphs on two war ships in San Francisco port, and spent two years with FTC (during which time his own company and his partner were pursued by justice for various financial frauds[11]). At FTC, he perfected the tube transistor to amplify radioelectric signals. The transistor turned out to be equally capable of working as an oscillator generating radio waves. The perfecting of vacuum tubes made it possible to go from the transmission of telegraphic radio pulses (Morse code messages) to voice transmission (radiophony) and earned Lee de Forest the Nobel Prize.

The potential of radio became so obvious that the US government passed a law forbidding foreign participation of over 20% in American radio stations and encouraged General Electric to buy an American subsidiary of the British company Marconi, to set up RCA (Radio Corporation of America). Once RCA had become owner of de Forest's patents, it aggressively defended its industrial property. FTC was however able to invoke its right of usage linked to the fact that the tube transistor had been developed in its laboratory. Sturgeon suggests, moreover, that the solidarity of electronics companies in San Francisco Bay (at this

[11] Elwell not only convinced FTC's owner, Beach Thompson, to hire Lee de Forest and provide him with two assistants, but also to pay bail to prevent him from being put in jail.

stage it is too early to speak of Silicon Valley) was partly a reaction to the aggressive behavior of RCA, which was trying to create a monopoly, and partly to the region's lack of legitimacy in the face of the East Coast giants (e.g. General Electric, AT&T)[12].

Sturgeon also notes that numerous inventions are the result of expertise developed at FTC. Most of these inventions were commercialized by new companies that were often created to do so, called spin-offs. Magnavox, for example, was created in 1910 to commercialize loud speakers. The invention of the synchronized tuner (commercialized by the Victor phonograph manufacturer) made it possible for a non-specialist to use a radio receiver using a single knob to tune in to the transmitter's frequency. The metal detector was invented by Fisher, one of Lee de Forest's former partners. Charles Lytton was hired by FTC when he left Stanford in 1928 to manage the vacuum tube department, and then stayed at Palo Alto until 1932, when in full-blown economic depression, FTC was forced by its shareholder to move to New Jersey[13]. There he developed the magnetron, a high-pressure vacuum tube indispensable for operating radars. Philo Farnworth developed television, but his invention was copied by David Sarnoff and Vladimir Zworykin at RCA. Ralph Heintz developed aerial radio contact, and then the gammatron, which was more efficient than the tubes made using Lee de Forest technology. A.M. Poniatoff invented the tape recorder (which was used from the start to store sounds and data) and created AMPex.

Most of these enterprises and their managers and technologists kept fairly close links with Stanford, sometimes exchanging access to laboratories and university expertise against donations of equipment. The community of radio amateurs — trespassing fiddlers on the

[12] Stephen B. Adams argues that a powerful sense of regional solidarity against exploitation and contempt by eastern firms fueled the growth of Silicon Valley [Adams 2003]

[13] It would be worth taking a closer look at the link between the "delocalization" of the sector's main company and the abundance of spin-offs.

cutting edge of technological possibilities — prefigured the *geek* community that was to inhabit Silicon Valley fifty years later.

Even if this episode set down the basis of a local culture, the electronic industry was not a big player in 1950, in an area where the county of Santa Clara[14] is referred to as the "prune capital of America" and where only 800 people (0.25% of the county) work in industry, half of them in the food industry [Rogers et Larsen, 1984].

The controversial role of military funding (the government's role)

Many of the electronic technologies developed in the Palo Alto region were civil or dual. Radiotelegraphy was initially used by commercial fleets. Radiophony provided a passion for numerous radio amateurs and, later on, radio broadcasting concerned mainly the media and the consumer (broadcasting and receiving material). Integrated circuits made it possible to perfect scientific instrumentation and improve computer performance and led to the invention of personal computers available to individual consumers, built around a microprocessor that integrated all the functionalities of the central processing unit. Hewlett-Packard's first big customer was Walt Disney for its Fantasia animation effects.

Nevertheless, Stuart W. Leslie reminds us that Silicon Valley had found a good training ground in the abundant military funding it received [Leslie 2000, Leslie 1993]. The technological enterprises whose stories we have just told made up a rich ecosystem, closely linked to a university that was remarkably open to its economic environment — yet all were modest in size until the Second World War. The war industry's needs meant that most of the better engineers, such as Frederic Terman, went to work in military laboratories or the arms

[14] Silicon Valley today mainly incorporates the county of Santa Clara, spreading from Palo Alto and Stanford University in the North to San Jose in the South, plus San Mateo county, located just to the north. During its heyday, it overflowed somewhat into the Santa Clara's neighboring counties.

industry on the East Coast. After the war, many military research results were royalty free[15], and this reduced the income of the East Coast giants. Companies from around Palo Alto remained at the cutting edge of technologies linked to micrometric waves (microwaves), and Stanford's electronic laboratory perfected the traveling-wave tube (which was an essential component of radar countermeasures[16]). The Korean War was a godsend for small companies, some of which grew very fast. Santa Clara county was sufficiently specialized in these very specific technologies to encourage companies from all over the country to open their laboratories there as soon as the aeronautics industry realized how important electronic technologies were becoming: Sylvania (1952), General Electric (1954) and especially Lockheed Missile and Space (1956). After winning the call for tender for the submarine missile, Polaris, and then a contract for surveillance satellites, Lockheed increased local staff levels from 200 in 1956 to 25,000 in 1964, becoming by far the biggest employer of the region.

The reduction of military budgets in the 1960s led to a decline in the microwave industry. Most of the companies did not manage to reposition themselves in a civil market, with the notable exception of Hewlett-Packard (which had a large number of civil activities from the start) and to a lesser extent Varian (which moved into scientific and medical instruments). Pressure from anti-military students pushed Stanford to distance itself from SRI (three-quarters of whose budget was at the time linked to military credits). But, despite its relatively

[15] Research financed by the Ministry of Defense could not be patented by companies.

[16] Electronic countermeasures are technologies that make it possible to dazzle, scramble or trick (depending on their degree of sophistication) adversaries' radars, helping fighter planes to avoid missiles and making them hard to locate on enemy surveillance systems.

fast decline[17], the microwave complex made way for the development of an ecosystem that was to turn out to be an asset for the burgeoning semi-conductor industry.

Start-ups or big companies? (technological spill-overs)

If the history of the semi-conductor industry in Silicon Valley is a succession of fast-developing start-ups (doubtlessly stemming from a discovery made at Bell Labs, in the shadow of the giant AT&T), there were other technological waves that were actually initiated thanks to big companies, such as magnetic storage. This technology dates back to the setting-up of an IBM laboratory in 1952 that aimed to attract local talents unwilling to go and work on the East Coast[18]. IBM developed hard disc and magnetic disc technologies, leading to numerous spin-offs (Shugart, Seagate, Quantum, Maxtor). But the IBM engineers also developed basic relational data technologies, few of which were exploited by the company itself, but which led to the development of large companies like Oracle, Sybase, Informix and consorts[19]. Similarly, the Xerox centre established in 1970 developed essential technologies for graphic interfaces, local networks (Ethernet) and workstations that especially contributed to the success of Apple and 3COM. Digital Equipment's Western Laboratories invented research motors and so made Google's fortune.

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[17] The fragile quality of start-ups' innovation and economic development was criticized by James Fisk, chairman of Bell Labs, which appealed to the State in 1965 to balance its policies to support the regeneration of established companies [Leslie 2000].

[18] This anecdote shows that Silicon Valley was therefore not a totally under-developed region. IBM, for example, chose not to set up its laboratory close to Stanford (like Lockheed and Xerox), but in remote San Jose.

[19] Kenney and von Burg (in [Kenney 2000] note that other IBM laboratories in Yorktown Heights (NY), Zurich and Tokyo did not stimulate the creation of multiple spin-offs and that there must therefore be "something linked to the local ecosystem".

The development of complementary institutions (the institutional eco-system)

Martin Kenney [Kenney 2000, Kenney and von Burg 2000] proposes a co-evolutionist vision to reconcile these approaches. In this outlook, the rapid development of high-tech companies fosters a system of institutions that, in turn, encourages the emergence of new companies, possibly in a different technological domain. This group of complementary institutions, which he refers to as “economy II” gathers together specialized company services, notably law firms providing very specific services and venture capitalists, which encourage the creation and development of new businesses. These institutions also include universities that are particularly open to their economic environment, as well as “community colleges” capable of rapidly integrating immigrants.

In an ecosystem of this kind, business creators have access to professional help for carrying out indispensable auxiliary tasks, like setting up the company’s legal status, recruiting personnel with indispensable skills, renting buildings and equipment, setting up a management control system adapted to expanding businesses and, obviously, financing, or even liquidating the company in case of failure. Many of these contributors are prepared to accept moderate fees in exchange for a stake in the company’s profits in the form of shares or sometimes the prospect of continuing to supply the company once it has become prosperous.

Mark Suchman [Suchman 2000] describes the very specific profile of Silicon Valley lawyers, who provide services that go far beyond simple legal advice. Unlike their traditional, more specialized peers in San Francisco, Silicon Valley lawyers are very integrated into the local community, they are experienced in start-ups, act as vectors of capitalization and spread good practices. They advise their customers not only on legal aspects, but also on their choice of economic model; they let them use their own network, find compatible partners for them, and often serve as a moral guarantee for venture capitalists. They have a pragmatic attitude, lying at the limit of the profession's ethical code, on the management of potential conflicts of interest, and sometimes represent both parties to a transaction if they agree. Since their reputation depends on the quality of those they recommend, they push their clients to respect the code of behavior that the community expects. Some law firms have seen rapid growth in line with that of Silicon Valley. One of the best known, Wilson, Mosher and Sonsini, grew from 12 staff in 1975 to 120 twenty years on, whereas San Francisco firms tried with little success to open offices in Silicon Valley or do more work there.

Just as Silicon Valley lawyers have little in common with their San Francisco counterparts, the venture capitalists grouped around Stanford, often on the Sand Hill Road, are mainly former engineers and entrepreneurs familiar with the local environment and technology, and willingly interventionist in companies on their portfolio, whose problems they understand well. They do not work in the same way as their peers, who tend to come from investment banking in Market Street, the "City" of San Francisco. Although the federal government encouraged the birth of venture capital with its Small Business Act of 1958, in which it offered two dollars of federal funds for one dollar of private financing in Small Business Investment Corporations (SBICs), most Silicon Valley companies opted for the more lucrative form of Limited Partnerships[20].

From this perspective, trying to pinpoint the key reasons for Silicon Valley's take-off is rather like debating whether the chicken or the egg came first. The waves of industrial prosperity that successively sprung from radiotelegraphy and radiophony, then microwave technologies, followed by integrated circuits and magnetic storage, micro-computing, multimedia, then

[20] A limited partnership can accept capital from institutional investors and does not have to disclose its operations. The pool of managers generally receives commissions proportionate to capital, and gets about 20% of any capital gains before general partners get their share.

internet software and biotechnologies, contributed to building or consolidating the institutions in this "second economy" that made it easier to surf on the next technological wave.

These institutions developed gradually. Stanford's openness to its economic environment was established from the microwave era, but it was still difficult to find investors. Shockley tried in vain to persuade Raytheon and Rockfeller's venture capital fund to finance his company, before he succeeded in convincing the south Californian entrepreneur Arnold Beckman to do so. Having not found a local investor, the Shockley Semiconductor renegades were finally presented to Sherman Fairchild, an East Coast entrepreneur (Fairchild Camera and Instrument Corp.). The fact that Sherman Fairchild could not secure their interest in the continued development of their business, even though it made them rich (after three years, he executed his option to buy out the founders' shares for $3M), facilitated the rapid succession of spin-offs (124 companies were created from Fairchild teams). These spin-offs made the fortunes of many people who were familiar with the new technologies, and facilitated the emergence of business angles and local venture capital.

How professional communities capitalized on knowledge (work organization)

Projects carried out within Silicon Valley businesses often called for highly specialized skills that the company would not need at other times. Specialists therefore tended to operate as very high-level independent consultants, going from one company to another, rather like medieval stonecutters moving round cathedral work sites. [Barley & Kunda 2004] show that communities of specialized experts did not only include very-high level gurus, but also more regular engineers and technicians, and that this new fabric of intermediaries made it possible to organize the market and made it more fluid.

Thus, an alternative economic model emerged. While in large companies, career-driven systems called on engineers' skills to take part in successive projects, and guaranteed them job stability in between specific temporary assignments, in Silicon Valley, professional communities of independent engineers (or employees with major billing agencies) served as skill pools available to companies to meet with temporary project needs.

Significant residual biodiversity (the culture of tolerance)

One of the reasons to explain how honest observers can use such different, sometimes contradictory, characteristics to define companies in Silicon Valley, is their extreme diversity. However enthusiastic the local community is, there will always be some hardheaded individuals that will resist the dominant culture. And this is an important factor to explain the ecosystem's resilience.

Annalee Saxenian, one of the better observers of Silicon Valley, provides numerous illustrations of open networking in her articles [Saxenian 1991]. Yet most of the companies that she used as examples fifteen years ago have since experienced serious difficulties or disappeared, whereas more closed and integrated companies, such as Apple, have prospered. Nevertheless, no Silicon Valley company is completely immune to influences and cultural contamination[21] .

Some authors have in fact linked Silicon Valley's creativity to the San Francisco area's tradition of great tolerance towards various waves of immigrants, sexual orientation and dress codes. Florida [Florida 2002] insists on the importance of a creative milieu favored by the

[21] The testimony of an HP manager, quoted by Saxenian, on the novelty of exchanging strategic information with suppliers, shows how this flagship Silicon Valley company had to adapt to the emergence of networks more than it would have chosen to. Also, if Apple is less open than other local companies, it shares many other traits with Silicon Valley's culture (like fun and challenge at work).

density of educated people around the university of Stanford, and the proximity to San Francisco.

Patrick Cohendet and Laurent Simon have taken Florida's intuition further, and shown how underground creative milieus in towns like Montreal have become involved with creative enterprises (e.g. video games, shows, animation, called "upperground"), thanks to the mediation ("middleground") of employees with a foot in both settings: "Ubisoft's research centre is Montreal city" [Simon 2009].

The co-evolution of technology, institutions, professional communities and markets

Through these multiple accounts, we can see that the factors favoring the emergence of clusters quickly appeared in what was to become Silicon Valley. The debate is rather as to what sparked off the emergence of a prosperous and adaptable ecosystem, and what enabled the rapid escalation of this emergence. Some interpretations put particular emphasis on one of the following factors: the existence of a reactive university open to its environment, an entrepreneurial tradition, solidarity between stakeholders in a peripheral region suffering from lack of legitimacy, the hazard of a highly promising technology, abundant state orders, the presence of shrewd venture capitalists, an attractive climate and a stimulating cultural environment, etc.

All of these factors unfurled over time, based on a chronology that could be set out as follows:

1849: the gold rush attracts large numbers of gold diggers to California, which becomes the USA's 31st state the following year

1864: construction of the peninsular railway is terminated

1874: Graham Bell invents the telephone (on the East Coast)

1891: Stanford University opens

1895: invention of the Marconi telegraph (first transatlantic transmission by radiotelegraph in 1901)

1909: Cyril Elwell creates Federal Telegraph with the help of Stanford's first president, David Starr Jordan, and buys the license for an electric transmitter from the Dane Vladimir Poulsen

1910: Magnavox, FTC's first spin-off

1911: Lee de Forest perfects the vacuum tube in Federal Telegraph's laboratory

1919: RCA (Radio corporation of America) is set up, following General Electric's takeover of American Marconi, backed by the Pentagon

1925: Frederick Emmons Terman is appointed professor at Stanford

1932: FTC is transferred to New Jersey, Charles Litton remains at Palo Alto and develops the magnetron

1937: the Varian brothers win a contract to develop klystron

1939: Hewlett-Packard is established

1945: Frederick Emmons Terman is appointed head of Stanford's engineering department and then university provost

1946: Stanford Research Institute (SRI), a Stanford consultancy subsidiary, is created

1952: IBM opens a subsidiary at San Jose to take advantage of local skills and work on magnetic data storage. A cascade of spin-offs result from the technology's development (e.g. Shugart, Seagate, Quantum, Maxtor). IBM also works on databases, setting off another cascade of spin-offs (e.g. Oracle, Sybase, Informix)

1953: William Shockley persuades Arnold Beckman to finance Shockley's semiconductor laboratories, which are set up at Mountain View

1953: the Korean War stimulates a big increase in the Pentagon's funding of supplies and research

1956: Lockheed Missile and Space, a Los Angeles aeronautics company, opens up a subsidiary for manufacturing electronic circuits in what is to become Silicon Valley

1957: Fairchild Semiconductor is set up by Shockley's "traitorous eight", who have been put in contact with Sherman Fairchild by the business banker Arthur Rock. The USSR launches Sputnik into orbit

1961: Thomas Davis and Arthur Rock create the venture capital fund Davis & Rock in San Francisco.

1962: Alza, one of the first "biotechnology" companies to be created in the area, is founded by Alejandro Zaffaroni.

1968: creation of Intel by Gordon Moore and Robert Noyce from Fairchild, bringing Andrew Grove with them

1969: SRI is privatized

1970: Xerox, a New Jersey company, creates the Palo Alto Research Center (PARC), which will go on to develop graphic interface technologies (ancestor of the Macintosh operating system), local networks (Ethernet), work stations and printers.

1972: creation of KPCB (Kleiner, Perkins, Caufield & Byers) a venture capital fund that has notably invested in Amazon.com, Compaq, Electronic Arts, Flextronics, Genentech, Google, Intuit, Lotus Development, LSI Logic, Macromedia, Netscape, Quantum, Segway, Sun Microsystems and Tandem

1976: the Apple computer is invented by Steve Jobs and Steve Wozniak with help from Mike Markulla from Hewlett Packard, who presents it to the venture capitalist, Arthur Rock. Creation of Genentech by biologist Herbert Boyer and venture capitalist Robert Swanson (production of insulin using recombinant DNA)

1984: Rogers and Larsen publish "Silicon Valley Fever", the story of the development of microelectronics and Silicon Valley. Len Bosack and Sandy Lerner found Cisco Systems. Kary Mullis develops DNA replication (PCR)

1991: Annalee Saxenian publishes a comparative analysis of Silicon Valley culture and the Boston region

1995: Netscape "industrializes" the Mosaic navigator of Illinois University (with its inventor) and enters the stock market with an impressive valuation, even though it has a low turnover and makes a loss: this is the first internet start-up and initiated the "bubble". Pixar, Steve Jobs' new company, enters the stock market. Louis Monier creates Altavista, a search engine that uses automatic web indexing, in Digital Equipment's Palo Alto laboratories.

Recipe for success: can Silicon Valley be cloned?

For those seeking to encourage the appearance of similarly dynamic ecosystems elsewhere, each of the preceding interpretations will lead to a different proposal. A partial model will result in a superstitious learning process and will increase the probability of acting on a single factor that would most likely not have produced anything without help from other factors, or that may in part simply be the consequence of other neglected characteristics.

Frederick Emmons Terman himself was often solicited, at the end of his long life, to give advice to regional authorities or universities wishing to duplicate the Stanford ecosystem, with diverse and often disappointing results. We are currently working on a more general analysis of different more or less successful attempts to replicate Silicon Valley elsewhere, based upon a range of models designed to potentially trigger success.

Finding the winning formula is all the more difficult given that there may well be more than one path that leads a modest region to prosperity.

On close inspection, and based on several complementary points of view, the story of Silicon Valley tends to point to a co-evolution of technologies, stakeholders, institutions and markets, relying on multiple interactions that are difficult to imitate.

Failing a detailed understanding of the mechanisms of this subtle process, promoters of regional ecosystems could give useful consideration to the wide variety of factors mentioned and try to identify and overcome weaknesses in their own environment.

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